DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORT OF TEST BY THE DIRECTOR OF FUEL RESEARCH ON THE CARBONISATION PLANT OF MIDLAND COAL PRODUCTS LTD., NETHERFIELD, NOTTINGHAM

Test carried out January 20th to 23rd, 1925

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PREFATORY NOTE

THE Department of Scientific and Industrial Research has been empowered by the Government to make tests at the public expense of plants for the low temperature carbonisation of bituminous coal. A copy of the published conditions for such tests is reproduced as an appendix.

The object of these tests is to place, in the hands of those interested, accurate technical data on the quality and quantity of yields, the throughput of the plant, the working temperatures, and the general ease of working, together with such other information as it may be possible to obtain under the limited conditions of the tests. It should be clearly understood that no attempt is made to pronounce on the commercial possibilities of plants which may be tested. The likelihood of commercial success can only finally be judged after working a plant under a steady load for a long period, and in the light of complete knowledge of local conditions such as cost of raw material, quantity of raw material available, price and markets for products, cost of labour, &c.

The present report deals with a test of two retorts of Midland Coal Products, Ltd., erected at Netherfield, near Nottingham. This plant is intended to utilise low grade slack coal, which is briquetted before carbonising. The retort is internally heated, which results in a diminution of the solid fuel produced, as compared with externally heated retorts, and the production of a large quantity of gas of a low calorific value (about 200 B.Th.U. per cubic foot). While such a process is economical thermally, and should be economical also as regards capital and labour costs, it necessarily depends for commercial success on the existence of a market for the gas produced.

The conclusions that may be drawn from the report are as follows :—

(1) The throughput and yields are approximately as claimed.

(2) The coke produced contains less volatile matter than ordinary " low temperature " coke and is not so free-burning ; it is very suitable for use in stoves, but not sufficiently free-burning for use in open grates unless these have a strong air draught.

(3) The plant showed certain defects, mainly in the auxiliary arrangements, which led to undue breakage of the briquettes and undue production of coke breeze. It is considered that there should be little difficulty in overcoming these defects.

C. H. LANDER,
Director of Fuel Research.

Department of Scientific and Industrial Research
16 Old Queen Street, Westminster, S.W.1.

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REPORT OF TEST ON PLANT OF MIDLAND COAL PRODUCTS, LTD., NETHERFIELD, NOTTINGHAM

Introduction

THE following report describes a test of the plant of the Midland Coal Products Company, carried out during January, 1925, by the staff of H.M. Fuel Research Station.

The plant consists of a battery of four retorts, each of a nominal capacity of 25 tons per day of 24 hours, together with the necessary auxiliaries for the collection of products.

The retorting principle adopted is the continuous carbonisation of coal pitch briquettes by internal heating. Both air and steam are passed into the lower portion of the retort, whereby a portion of the coke produced is consumed and the sensible heat of the resulting hot gases carbonises the incoming briquettes at comparatively low temperatures.

Under normal conditions of working the plant is supplied with briquettes from the Butterley Coal Company at Kirkby, 15 miles distant from the plant. For the purpose of this test it was originally arranged that breakage by transport should be obviated by preparing sufficient briquettes at Colwick. This arrangement was not carried through to a satisfactory conclusion as inclement weather caused the briquetting to be done on wet coal and the briquettes produced were friable and produced very little less dust than the imported ones. Lack of capacity in the Colwick plant also made it essential that part of the test should be run on imported briquettes.

The test was made on two retorts and occupied 72$\frac{1}{3}$ hours. During the test, 200·5 tons of briquettes were handled, but only 138·7 tons were charged, the reject, being the dust produced by breakage, amounting to 29·1 per cent. of the Colwick, and 33·8 per cent. of the Butterley Company briquettes. The throughput realised was therefore 23·0 tons per retort per day or within measure of the rated value. The amount of dust rejected was obviously abnormal and was a result of using wet coal and an unsuitable elevator. It was impossible to determine the minimum reject under the best conditions, but a very considerable improvement in briquetting efficiency should be obtainable. Any improvement would also mean a lower consumption of pitch and less breeze in the coke.

The temperature of the hot zone in the retort is at present controlled by varying the rate of charging and discharging.

It is possible that a more satisfactory control could be obtained by a mechanical discharge maintaining a constant throughput,

coupled with a constant air supply. The working variations should then be sufficiently small to be capable of control by slight alterations to the steam supply.

The saleable products produced per ton of briquettes were as follows :—

Coke, 6·38 cwt. (not including 1·14 cwt. of breeze).
Gas, at 60° F. and 30 in. satd., 58,300 cubic ft., equivalent to 112·5 therms.
Oil, 8·2 gals. containing 2·8 gals. tar acids.

The figure for the coke product given above does not include the 15·2 per cent. of breeze produced. As this breeze is returned to the briquetting plant, it represents loss of throughput both in this plant and in the retorts. For every 10 per cent. of breeze produced the unproductive work done is about 3·8 per cent.

The tar produced, 21·0 gals., is divisible by distillation into oil, 8·2 gals., and pitch, 142·8 lb. The oil has now a ready market as " creosote oil," while the pitch, under favourable briquetting conditions, should be sufficient to supply the briquetting plant.

The gas is excellent for use in gas engines, under boilers, and for general furnace work. It is low in carbon dioxide and has a calorific value of 190 to 200 B.Th.U. per cubic foot.

The plant as a whole is limited in application to districts in which there is a demand for power gas in large quantity and where coal slack can be purchased cheaply. Granted the demand for such gas the plant has the following points in its favour.

(1) The utilisation of coal slack for which there may otherwise be little outlet.
(2) High thermal efficiency.
(3) Low capital cost and comparatively high throughput.
(4) Moderate labour costs.

The disadvantages which may be offset against these may be detailed as follows, but none of them is serious :—

(i) The necessity for expensive pipe-lines for gas supply in a district where the gas is not used in the immediate vicinity.
(ii) The necessity for air-drying the coal slack used and the cost of pre-briquetting that slack with pitch.
(iii) The fact that the smokeless fuel produced is limited in its application to stoves, and to such open domestic grates as have a strong air draught.

PRELIMINARY ARRANGEMENTS

A preliminary visit of inspection was made to the carbonising plant of the Midland Coal Products, Ltd., on 23rd December, 1924, by Mr. J. G. King (Chief Chemist) and Mr. W. J. Skilling, and arrangements were made for the carrying out of such alterations and for the making of such additions to the installation as were thought necessary for the purposes of a satisfactory test.

The 12th January, 1925, was agreed upon as the date for commencing the operations, subject to there being sufficient briquettes available to carry out a test of at least 48 hours' duration.

A second visit was made on 13th January, 1925, by Mr. Skilling and Mr. T. F. Hurley, to supervise the installation of a Kent Steam Meter, and to carry out a test on the briquetting plant, the purpose of the latter being to ascertain the proportion of pitch added to the briquettes as a binder and, from samples taken, to find what proportion of the binder could be extracted by the use of a suitable solvent. Final arrangements were made to begin the test on Tuesday, 20th January, and it was decided to use only two of the four retorts available, each retort being capable of dealing with one ton of briquettes per hour.

On Monday, 19th January, the testing staff, consisting of Messrs. Skilling, MacDougall, Hurley and Linnel, arrived at the Company's premises and proceeded to inspect the plant and make preparations for starting the test on the following day.

The test was witnessed on behalf of the Midland Coal Products, Ltd., by Mr. C. Ingman, Manager, and Mr. J. E. Truzzell, Engineer, the latter attending during the night.

DESCRIPTION OF PLANT

Diagrams of the plant are shown in the Figure (at end).

The plant consists of a battery of four retorts with air and steam supplies, briquette elevator and storage bunker, coke elevator and screen, Lymn washer, exhausters, saw-dust scrubbers, rotary meter for gas, and separating tanks for tar and liquor.

The retort, as shown in the section, consists of a long tapering vertical cylinder, having an internal diameter at the top of 4 ft. 4 in., increasing to 5 ft. 6 in. diameter about 5 ft. from the bottom. The bottom section is in the form of an inverted cone, the discharging door being at the apex. A ganister brick lining, 15 in. thick, extends over a distance of 12 ft. and the bottom cone-shaped section is water-jacketed. The gas off-take is on a level with the charging hopper, the latter being fitted with inner and outer doors and having a capacity of 5 cwt. of briquettes. The discharging door is semi-circular in shape, is water-sealed, and is opened and closed by hand. About 1 ft. above the widest part of the retorts there is a series of twelve tuyères through which air and steam are passed into the interior. Below the water-jacketed cone are four $\frac{3}{8}$-in. diameter steam jets, which supply steam for partially cooling the coke before discharge.

Erected centrally over the four retorts is the storage bunker, attached to which is a movable discharge chute capable of feeding all the retorts.

The capacity of each retort is about 5 tons and that of the overhead bunker 12·5 tons.

Each pair of retorts has a common gas main leading to the Lymn washer which is a tower 45 ft. high and 6 ft. in diameter, fitted with a series of baffles to deflect the water flowing downwards

and is capable of dealing with 250,000 cubic feet of gas per hour. Beside this washer are three exhauster fans, two of which are always working in series. These are followed by three tar-fog scrubbers. These scrubbers are boxes packed with alternate layers of chippings and sawdust, there being six layers 6 in. deep in each box. One box has sufficient capacity for two retorts and only one was in use during the test. From these scrubbers the gas passes to a rotary meter.

Adjacent to the condensing and scrubbing plant are collecting and settling tanks for dealing with tar and liquor.

OPERATION OF PLANT

Briquettes are hand-forked from the wagons into the elevator boot from which they are carried by a plate elevator to the storage bunker above the retorts. From this bunker to the retort charging hopper, the briquettes pass over a $\frac{1}{2}$-in. screen to remove the fine material broken from the briquettes. The charging hopper of the retort is filled with briquettes every fifteen minutes, the outer cover replaced and the inner door opened allowing the charge to drop into the retort.

Carbonisation is carried out entirely by internal heating. This is effected by burning part of the material charged within the retort. Air and steam are passed in at the tuyères, in the vicinity of which combustion takes place, and the hot gas, passing upwards on its way to the off-take pipe, serves to heat the incoming briquettes. The carbonised briquettes are rapidly cooled on passing through the water-jacketed zone and are discharged at a temperature of about 600° C. The quantity of coke withdrawn is equivalent in bulk to a charge of raw briquettes.

The coke is quenched on an iron plate immediately below the retorts and pushed into the boot of a small bucket elevator which delivers it to a revolving screen, where it is separated into three sizes, viz., breeze (below $\frac{1}{2}$-in.), medium coke ($\frac{1}{2}$-in. to $1\frac{1}{2}$-in.), large coke (over $1\frac{1}{2}$ in.), and dropped directly into wagons placed beneath the screen.

Pokering of the charge in the region of the tuyères takes place about twice every shift, in order to loosen any clinker which may tend to form in this zone and so hang up the charge.

The gas "make" passes through a water-seal and then along the main to the Lymn washer, in which it meets a descending spray of water which is deflected by baffles. The quantity of water used varies according to the prevailing atmospheric temperature, but averages about 2,000 gallons per hour. A large proportion of the tar is thus removed from the gas, the remainder being separated by the two exhauster fans, which are also supplied with two jets of water. The gas then passes through the saw-dust scrubbing box to the rotary meter.

A very small quantity of tar collects at the water-seals of the retorts and at the saw-dust scrubbers, the bulk being drawn from the bottom of the Lymn washer and the exhauster fans. The tar

removed by the exhauster floats on the surface of the liquor in the form of an emulsion and collects in the first bay of the separating tank (*see* Figure). From this bay it is ladled to a channel which carries it to the " wet " tar tank, where the emulsion is broken down by steam heated coils and the tar removed to the separating tank. Settled tar is drawn from the bottom of the Lymn washer and from the separating tank as occasion demands and is pumped into the overhead settling tank, where a further separation of liquor is obtained. The tar is then passed to the " dry " tar tank and the liquor flows to the drains.

ARRANGEMENTS FOR TEST

It was originally intended to carry out the test entirely on briquettes made in the briquetting plant at Colwick from $\frac{1}{2}$-in. washed slack (top hard seam) and medium hard coal-tar pitch, but as only 100 tons (gross, no allowance for breakages) of this material were available it was decided that the test should be of three days' duration and that, on exhaustion of the above supply, a slightly larger briquette, made from the same coal and the same type of pitch at the Butterley Coal Company's Colliery at Kirkby, should be used.

Arrangements were made to start the test with the storage bunker completely full, and the retorts with full charge, *i.e.*, with briquettes at a depth of 6 ft. from the top of the retorts, all other briquettes, dust and coke to be cleared away. The tanks, with the exception of the separating and dry tar tanks, and the seals were to be drained of tar. Likewise the settling tank by way of which the effluent left the works were to be cleared of any tar it might contain.

As soon as these conditions were attained it was intended that the gas meter should be read, cocks on the tar tanks closed, empty tared trucks placed under the coke screen and the elevation of weighed quantities of briquettes commenced. The overhead settling tank and the dry tar tank, into which all surplus tar had been pumped, were then cleaned in readiness to accommodate the " make."

CONDITIONS OF TEST

The test was timed to start at 10 a.m. on Tuesday, 20th January, but it was found that the desired conditions had not been attained by that hour. Later it was seen that these conditions could not be realised as far as the tar tanks were concerned, owing to the stock tanks being full, and it was therefore decided to start the test at 1.30 p.m., noting the level of the briquettes in the bunker, the reading on the gas meter, and dipping and sampling tar tanks where found necessary.

Arrangements were made for the plant to be kept under continuous observation by the Fuel Research Station staff throughout the duration of the test.

The following instructions for routine observations were adhered to throughout:—

(1) *Briquettes.*—Wagons of briquettes to be weighed, discharged into elevator boot and the wagon with briquette dust re-weighed. The broken material or "fines" to be discharged and the wagon tared.

All fine material passing through the ½-in. screen on the retort charging platform to be passed down the chute to a truck and weighed; twelve briquettes to be collected from each charge of 5 cwt. fed to the retorts, giving a sample of about 1 per cent. for analysis.

(2) *Coke.*—Tared trucks to be placed in position under coke screen to catch breeze, medium and large coke, separately, and when full removed and weighed. The material in each truck to be levelled periodically, and when truck is a quarter full, five shovelfuls of coke to be taken, one in the centre and one near each corner. This operation to be repeated at half, three-quarters and full truck. This represents a sample of over 1 per cent.

(3) *Gas.*—Meter reading of gas make to be noted every two hours.

Calorific value of gas to be determined every two hours.

Specific gravity of gas to be taken every two hours.

An average gas sample to be taken at the rate of 20 c.cs. per hour.

(4) *Tar and liquor.*—Tar tanks to be kept under observation. Tar to be drawn from the Lymn washer, separating tank and wet tar tank as occasion arises, pumped to overhead settling tank, freed from liquor, and run into dry tar tank. When the latter tank is full, measure, sample and pump tar to storage. Liquor to be neglected owing to its high dilution.

(5) *Steam.*—Consumption of steam to be noted every two hours.

Special observations to be made as found convenient:—

(1) Temperature of combustion zone.
(2) Skin temperature of the retorts, using surface thermometer.
(3) Estimation of the amount of water in gas leaving retorts.
(4) Labour and power used.
(5) General working conditions.

The test proceeded without interruption until Friday, 23rd January, at 1.30 p.m. On Thursday, 22nd, at 12.15 p.m., the briquettes manufactured at Colwick were consumed and were

followed by the larger Kirkby briquettes. At the finish, the storage bunker was brought to the starting level, as also were the retorts : tar collecting tanks were drained to the starting conditions, measured and sampled, all excess being pumped to the dry tar tank where it was measured and sampled as " tar make." These conditions being simultaneously attained, the gas meter was read, the coke wagons withdrawn from beneath the screen, and the briquette wagon being discharged was removed for re-weighing.

The various samples taken throughout the test were collected, and, where possible, briquette and coke samples were reduced in bulk by quartering, and despatched to the Fuel Research Station at East Greenwich.

BRIQUETTES USED

The briquettes used in the test were made from washed top hard (Nottinghamshire) $\frac{1}{2}$-in. slack, mined by the Butterley Coal Company, Ltd., at Kirkby, near Nottingham, with ordinary coal-tar pitch as a binder. The slack contains originally about 30 per cent. of ash, but after treatment in a Rheolaveur washer, this is reduced to 5 per cent.

Two sizes of briquettes were used, those made in the small plant beside the retorts at Colwick weighed about $2\frac{1}{2}$ oz., the large ones made at Kirkby weighed about 5 oz. They are ovoid in shape and comparatively hard when cold.

The total weight of briquetted material amounted to 200·5 tons, but of this 61·75 tons were removed by the screens as " fines," representing 30·8 per cent. of the total.

The quantities of the two sizes used were as follows :—

——	Gross weight.	" Fines."	Net weight.
	Tons.	Tons.	Tons.
Midland Coal Products (small)	127·7	37·2	90·5
Butterley Company (large) ..	72·8	24·6	48·2

The percentages of " fines " in the small briquettes and the large were respectively 29·1 and 33·8.

It may be mentioned here that the quantity of broken material appears excessive and is due to two causes, the first of which is probably the more important :—

(1) The excessive amount of moisture in the coal as briquetted. Air-dry coal would have produced much stronger briquettes with less pitch, but temporary local conditions prevented air-drying during the test.

(2) The elevator available was of an unsuitable type.

The analyses of the "slack" and the two sizes of briquettes used are given below :—

—	Average sample of ½-in. washed slack.	Colwick briquettes as charged.	Kirkby briquettes as charged.
Proximate Analysis—			
Moisture	9·57	14·13	14·46
Volatile matter (less moisture)	32·48	34·75	33·31
"Fixed carbon"	52·58	46·35	47·12
Ash	5·37	4·77	5·11
	100·00		
Ultimate Analysis on Dry Material—			
Carbon	77·72	79·10	77·36
Hydrogen	4·91	4·94	4·46
Sulphur	0·96	0·83	1·21
Nitrogen	1·94	1·57	1·47
Oxygen	8·53	8·00	9·53
Ash	5·94	5·56	5·97
	100·00		
Calorific value, B.Th.U. per lb. (dry basis)	13,650	13,969	13,944
Percentage of pitch in briquettes (dry basis)	—	8·0	10·0

The slack has low caking power.

In the crucible test, the button is dull grey in colour, cellular but not swollen, and fairly hard. The briquette mixture gives a similar button, which is slightly stronger.

The pitch is described as medium hard coal-tar pitch, being the residue left on distilling coal-tar to about 360° C. The percentage of this material soluble in carbon disulphide is 85·1.

The proportion of pitch to dry slack averages about 8 to 10 per cent. On analysis the pitch furnished the following figures :—

Carbon	88·86
Hydrogen	6·94
Sulphur	0·64
Nitrogen	1·46
Oxygen	1·18
Ash	0·92
	100·00

Calorific value, 16,000 B.Th.U.'s per lb.

Laboratory Assay at 600° C. (Dry Basis)

	Colwick briquettes yield per 100 grm.	Kirkby briquettes yield per 100 grm.	Mean yield per ton of briquettes.	Slack used in briquettes.
Coke	69·9	72·0	14·2 cwt.	73·4
Oil	17·4	16·3	37·5 gals.	12·4
Gas	7·3	6·3	3,120 cu. ft.	9·4
Liquor	5·5	5·3	12·1 gals.	4·8
	100·1	99·9		100·0

The temperatures of apparent decomposition in the assay apparatus were similar in the cases of the two briquettes and were as follows, water at 300° C., oil at 330° C., and gas at 415° C.

The coke in each case was fairly dark and without lustre; easily broken and showed little sign of swelling; that from the slack was non-coherent.

It must be emphasised that no comparison can be drawn between these figures and those obtained in the actual test since widely different temperatures are used. The assay figures, when the correlation factor has been taken into consideration, may be assumed to indicate the results obtainable by the low temperature carbonisation of this material.

Briquetting

The same method of briquetting the slack is in use at Kirkby Colliery and at the carbonising plant at Colwick.

Drained washed slack is fed into a mixer of the screw conveyor type where it is mixed with pitch from a beaker. The mixture is then conveyed to a bar disintegrator where it is further reduced in size to $\frac{1}{10}$-in. mesh before being passed to the heater and mixer. This vessel is kept at a temperature of 300° C. by superheated steam. The hot material is fed from this mixer to a pug mill where it is stirred and cooled to about 60° or 70° C. before briquetting in a Yeadon press.

The briquettes are delivered to wagons after passing over a screen. They harden on cooling and are then discharged into the elevator boot.

At Colwick the machine was set to make a briquette containing about 8 per cent. pitch.

Samples of slack, pitch, and the briquetted material were extracted in the laboratory by hot carbon disulphide. The extract was as follows:—

	Per cent.
Dry slack	0·2
Dry pitch	85·1
Dry briquettes	6·8

6·8 per cent. of extract from the briquettes therefore corresponds to a pitch content of 8·0 per cent.

The percentage of pitch in the average sample of Colwick and Kirkby briquettes was 8·0 and 10·0 per cent. respectively.

WEIGHT, CARBON AND THERMAL BALANCES

The quantity of liquor produced caused a difficulty in the preparation of a weight balance for the test. Owing to the enormous and varying quantities of water supplied to the Lymn washer (approximately 2,000 gallons per hour) and the lack of facilities for its measurement, it was decided to make no attempt to deal with it. An apparatus was fitted up to estimate the total condensable products in the gas leaving the retort, but this was unsatisfactory as a very efficient condensing and scrubbing system could not be used on account of the tar solidifying and blocking the tubes. The results obtained were valueless.

The following figures show the quantity of materials handled during the test, exclusive of liquor :—

	Tons.
Briquetted as charged (14·24 per cent. moisture)	138·75
Steam to retorts	11·06
Air to retorts (calculated) ..	171·00
	320·81
Coke discharged (dry)	52·08
Tar collected (dry)	13·99
Gas collected (saturated) ..	230·40
Clinker collected	0·01
	296·48

The difference in these totals, 24·33 tons, should cover the losses and liquor produced. Taking the average figure for water of decomposition obtained by carbonising the briquetting mixture in the laboratory assay apparatus, the total liquor amounts to 26·16 tons, showing a gain of 1·83 tons or 0·57 per cent.

The weight of air to retorts was calculated from the percentage of nitrogen in the gas. The considerable quantity of gas lost is equivalent to a greater quantity of air injected (as Sp. gr. of gas is 0·8 for air = 1), so that the weight balance appears better than it really should.

A further attempt to check the weight balance was made by calculating the carbon in the charged briquettes and in the products.

	Tons.
Carbon in briquettes	93·4
Carbon in—	
Coke	43·8
Gas	37·8
Tar	11·9
	93·5
Carbon loss	− 0·1

This balance, showing a gain of only 0·1 per cent., may be taken as a fairly satisfactory check in the absence of complete data concerning the weight of all the materials handled in the test.

A thermal balance of the products and heat changes in the setting was calculated and gave the following results :—

	Therms.	Therms.
1. Potential heat in briquettes ..	37,208	
Potential heat in—		
Gas		15,613
Coke		14,419
Tar		5,112
Difference		2,064
	37,208	37,208
2. Potential heat in briquettes ..	37,208	
Sensible heat in—		
Steam	276	
Air	Nil	
Potential heat in products ..		35,144
Sensible heat in—		
Gas		555
Coke		438
Tar		84
Liquor (24·33 tons)		666
Heat dissipated from setting (by difference)		597
	37,484	37,484

The loss of potential heat in the process of carbonisation is 5·5 per cent. and can be regarded as satisfactory.

The second balance sheet, dealing with the various heat losses such as sensible heat in the products and that lost by radiation, conduction and convection appears extremely satisfactory, but it must be remembered that the figure for the liquor is assumed.

Losses by radiation and convection from the producer shell, and by conduction to the water in the lower section, appear by difference to be 597 therms which is 1·6 per cent. of the potential heat in the briquettes charged.

By calculation from the surface temperatures of the two retorts in use (*see* page 19) and the assumed range through which the coke was cooled in the water-jacketed portions, an approximate figure for these losses was obtained amounting to 143 therms from the two shells and 390 therms in the cooling water, making a total of 533 therms or 1·44 per cent. This is in remarkable agreement with the figure obtained by difference above, but

cannot be assumed to be correct to within 30 per cent. owing to the limited data available.

The complete analyses of the briquettes and the various products of carbonisation were carried out at the Fuel Research Station, and the results are set out under their several headings in the subsequent pages.

GAS

The gas leaves the retorts at an average temperature of 220° C, passes through the Lymn washer, then through the exhausters and the saw-dust scrubbers to the meter, and is disposed of to the Power Station, the tar still and the steam boiler, the laboratory and offices, and the surplus is burned at a branch pipe. The supply to the laboratories was carried in a two inch pipe and as the heating apparatus was supplied by this pipe, there was little or no time lag to take into account in collecting the gas sample in the laboratory, and estimating its calorific value and specific gravity.

A Simmance calorimeter, and a diffusion bell were used respectively for the calorific value and specific gravity determinations.

A graph (at end) has been drawn showing the make, calorific value and specific gravity of the gas, and the steam supplied to the retorts over periods throughout the test. It will be noticed that about midnight on Wednesday and noon on Thursday there is a considerable drop in the make. In both instances it was found that the valve on the surplus gas pipe was almost closed and this threw a serious back pressure on the retorts causing large quantities of gas to escape at the charging and discharging doors. On enquiries being made it was discovered that the boiler attendants were tampering with the valve in order to increase the gas supply to the boiler.

The calorific values and analyses of the various gas samples taken throughout the test are shown in the accompanying table (page 13).

8,089,700 cubic ft. of gas (at 60° F. and 30-in. pressure), were produced during the test which corresponds to an average yield of 58,000 cubic ft. per ton of briquettes.

The composition of the gas remained very uniform throughout. The analyses show no unsaturated bodies, but in special samples these have been found to amount to about 0·3 per cent. It is somewhat similar in composition to a semi-water gas made from bituminous coal. The low percentage of carbon dioxide present is a notable feature.

Gas Analysis

	1	2	3	4	5	6	7	8	9	10	11	Average
Volume of gas produced per hr./cu. ft.	99,500	109,500	118,200	118,200	102,200	112,800	95,700	119,200	124,000	113,800	116,400	113,600
Period of sample hrs.	5·5	8·0	9·0	7·0	6·0	6·0	6·0	8·0	6·0	6·0	4·7	—
Analysis—												
CO_2		1·8	1·0	1·2	1·7	1·6	1·6	1·5	2·4	2·0	1·4	1·6
O_2		—	—	—	—	—	—	—	—	—	—	—
CO		27·5	28·7	28·1	28·1	27·1	28·2	29·8	27·6	28·2	27·5	28·1
H_2	Sample	17·7	15·0	17·5	17·7	17·4	17·8	15·6	15·8	14·5	17·0	16·6
CH_4	Lost.	4·3	5·1	4·3	3·7	4·2	4·0	3·6	4·6	5·3	5·0	4·4
N_2		46·7	50·2	48·9	48·8	49·7	48·4	49·5	49·6	50·0	49·1	49·3
	100·00											
Specific gravity (air = 1) ..	0·82	0·83	0·82	0·83	0·82	0·83	0·84	0·83	0·84	0·84	0·84	0·83
Calorific value, B.Th.U. per cu. ft.—												
Calculated ..	—	187	190	188	183	184	187	181	185	188	191	186
By calorimeter ..	194	192	197	198	198	184	185	191	196	195	192	193

COKE

The coke when discharged from the retorts was at a dull red heat, and was of such a nature as to require little quenching. It was then delivered to the revolving screen which separated it into three sizes, large, medium and breeze. The proportions obtained from the two sizes of briquettes used in the test were as follows :—

Coke from—	Large (over 1½ in.).	Medium (1½ — ½ in.).	Breeze (under ½ in.).
	Per cent.	Per cent.	Per cent.
Colwick (2½-oz. size)	37·4	45·8	16·8
Kirkby (5-oz. size)	46·7	41·8	11·5

The Kirkby briquettes gave the larger proportions of saleable material, but it was observed that the quantity of briquettes which reached the finished state in a whole condition was extremely small.

The coke was dull grey-black in appearance, but when fractured exposed a surface with a greyish lustre, was very hard and compact, and had close cellular structure.

The samples sent in sacks by rail to Greenwich arrived without any apparent breakage, little or no dust being produced in transit.

Results are shown below of the proximate and ultimate analysis and also of the calorific value determination.

	Large Coke.	Medium Coke.	Breeze.*	
			As Analysed.	Calculated.
Proximate Analysis—				
Moisture	2·10	1·63	3·30	—
Volatile matter, less moisture	2·18	1·45	15·00	1·90
" Fixed carbon " ..	86·44	83·87	65·10	74·60
Ash	9·28	13·05	16·60	23·50
	100·00	100·00	100·00	100·00

* *See* remarks below.

——	Mixture of Large and Medium Coke in Ratio 1 : 1·1.	Breeze.*	
		As Analysed.	Calculated.
Ultimate Analysis (Dry Basis)—			
Carbon	86·19	75·40	73·30
Hydrogen	0·58	2·34	0·88
Sulphur	0·91	0·98	1·06
Nitrogen	0·82	1·13	0·89
Oxygen (difference) ..	0·03	2·97	0·14
Ash	11·47	17·18	23·73
	100·00	100·00	100·00

Large Coke.	Medium Coke.	Breeze (calculated).
Calorific Value—		
12,713	12,175	B.Th.U. per lb. 11,320

* *See* remarks below.

It will be seen that the analyses of the coke breeze gives abnormal results, and it seems impossible for the figures to be correct, and it appears that the sample must have been contaminated with briquette dust. A certain amount of briquette dust was blown into the coke wagons throughout the test, but not sufficient to account for the high volatile content determined. At the end of the test a sample which had been taken of the briquette fines could not be found, and it was thought that it might have been mixed with the coke breeze sample. Assuming that such mixing had taken place the volatile content of the coke and of the briquettes gives a basis for ascertaining the proportion of the coke breeze and briquette fines in the mixture, and indicated that the proportion was one part of briquette dust to 1·6 parts of coke breeze. The " calculated " figures for the analysis of the breeze, which are given above have been prepared on this basis and appear reasonable.

A further check is obtained by calculating the ash content of the briquettes and the coke. Taking the ash content of the breeze " as analysed " :—

	Tons.
Ash in briquettes	6·78
Ash in Coke—	
Large	1·99
Medium	3·07
Breeze	1·31
Clinker	0·01
	6·38

The difference shows a loss of 0·4 tons of ash. If, however, the ash in the breeze is taken " as calculated " (23·5 per cent.), the ash in the coke totals 6·8 tons, or a gain of 0·3 per cent. instead of a loss of 6·2 per cent., indicating that no serious contamination of the " breeze " collected in the wagon had taken place.

The coke is not suitable as a universal fuel for use in domestic open grates as it requires too strong a draught for continuous combustion and is also difficult to ignite. It is, however, a very suitable fuel for domestic stoves.

TAR

All measurements of the tar made during the test, were done in what was called the " dry " tar tank. The wet tar from the various tanks was intermittently pumped into the overhead settling tank and heated to a temperature of about 60° C. by means of steam coils. Much of the liquor was separated and the tar run into the " dry " tar tank where it was measured and sampled. The tank in which this measuring was done was rectangular in shape measuring 9 ft. by 8 ft., a dip of 1 in., representing 37·4 gallons.

The yield of tar (dry) was 13·99 tons or 2,911 gallons with a specific gravity of 1·076. This is equivalent to a yield of 21·0 gallons per ton of briquettes, or 10 per cent. by weight.

Preliminary Distillation (*Percentages by Weight of Dry Tar*)

——	Per cent.	$D\,^{15}_{15}$
To 170° C.	1·1	0·86
170–230° C.	3·9	0·95
230-270° C.	4·1	0·99
270–360° C.	26·9	1·03
Pitch	63·2	
Loss	0·8	
	100·0	

Note.—Tar acids = 13·45 per cent. by volume or 2·8 gallons per ton of briquettes.

At ordinary temperatures the tar is in a semi-solid condition which makes it difficult to handle and renders the use of steam coils in the storage tanks necessary. The practice at the carbonising plant is to pass the hot fluid tar straight to a continuous still, and there distilling off the oils, the pitch being sent to the briquetting plant. The yield of oils below 270° C. is very low, being about one-fourth of that obtained from a low temperature tar, although the specific gravities are very similar. On the other hand the oil above 270° C., and the pitch, are high in proportion

due probably to re-distillation of the binding material from the briquettes. For the purpose of the carbon balance sheet the carbon content of the tar was determined and found to be 84·89 per cent.

LIQUOR AND AMMONIA

Owing to the dilution of the liquor in the Lymn washer, its measurement was not attempted. The liquor is run through the settling tank and thence to waste after passing a second settling tank for the removal of traces of tar.

A sample of this liquor gave the ammonia content as 0·06 oz. per gallon, showing that recovery of ammonia was impracticable.

In the attempt to condense the liquid products at the gas off-take of the retort, a quantity of liquor was obtained corresponding to 10·5 gallons of liquor per ton of briquettes. This liquor on distillation yielded 0·81 per cent. of ammonia by weight.

GENERAL OBSERVATIONS

The installation of four retorts, two of which were under observation for 72·3 hours, was stated to have a throughput of 100 tons of briquettes per 24 hours. The total weight of material carbonised was 138·75 tons.

——	Two Retorts.	Four Retorts.
	Tons.	Tons.
Briquettes carbonised—		
Per 24 hours	46·00	92·0
Per hour	1·92	3·84
Per retort per hour	0·96	0·96

This throughput is 8 tons short of that claimed, but could be raised to the specified figure by increasing the rate of charge and discharge from the retort.

The briquettes received too much handling before reaching the retorts, and this was particularly the case with the briquettes made on the works.

The elevator (plate type) is unsuitable for carrying briquettes as these are subjected to the abrasive action of the elevator casing, causing a continuous shower of fine material to be deposited in the immediate vicinity. A hoist or inclined conveyor would reduce both breakage and loss of dust.

Charging of the retorts should take place every 15 minutes, but as many as three charges in rapid succession have been observed. There was pronounced leakage of gas at the charging platform which, however, was not due to the type of cover on the hopper. The covers are designed with a guard ring attached, which is intended to fit over the rim of the open hopper and so protect its surface from becoming coated with grit and thus preventing the cover from fitting closely. The protecting rims

are never used, with the result that an incrustation fully half-an-inch thick forms between the cover and the hopper at the side opposite the bolt round which the cover revolves. It would appear that the manipulation might be improved.

Discharging of coke which should immediately precede charging was also an erratic performance. The hot zone within the retort is controlled by the rate of discharge, large discharges are sometimes made resulting in partially carbonised briquettes being withdrawn. Some attempt at temperature control might be made by regular charging and discharging, and by fixing the steam and air supply at a constant amount.

The fierce heat in the region of the tuyères causes clinkering, although only to a very slight extent. This could be avoided by a reduction of the air velocity, but possibly at some sacrifice in not forcing air to the centre of the charge. The heat imparted to the water in the cooling zone was not utilised in any way, and an unnecessary large waste of water took place at the seals of the discharging door.

An examination of the graph shows that the amounts of steam used and gas measured were erratic, particularly the latter. The steam indicates considerable periods of steady supply and the variations are accounted for by intermittent use of the "cooling-steam." As regards the gas make, it was known that losses were being accentuated by back pressures being thrown on the retorts, but any other cause beyond excessive drawing of charges and lowering of retort temperature, cannot be stated. Between 1.30 and 4.30 a.m. on the Wednesday morning and after 4 p.m. on the Thursday, the steam supply and gas make tend to follow each other.

With regard to the carbonisation of the briquettes only a partial low temperature carbonisation appeared to take place, because flames were always visible through the sight hole at the tuyères.

TEMPERATURES

No actual measurements were possible within the retorts for the following reasons:—

1. The presence of flames precluded the use of an optical pyrometer.
2. No thermo couple with a metal casing capable of withstanding the oxidising atmosphere in the region of the tuyères was available.
3. Silica-cased pyrometers could not be used owing to the movement of the charge.

It was, however, estimated that the temperature within increased from about 200° C. at the top to about 1200° C. in the region of the tuyères when combustion was taking place.

In order to measure the heat losses due to radiation, the temperature of the metal casing of the retorts was taken by means

of a surface thermometer. Separate figures were obtained for the three sections of the retorts and the average value is shown below :—

	Retort 1.		Retort 2.
Section 1	43° C.	Section 1	51° C.
Section 2	81° C.	Section 2	86° C.
Section 3	119° C.	Section 3	106° C.

The bottom section was water-jacketed and as no facilities were provided for measuring the quantity of water passing or its temperature, the assumption was made that the coke cooled from 1200° C. to 600° C. in this zone.

On page 11 the results of a calculation showing the various heat losses are set forth, but as already stated these can only be taken as rough approximations owing to the imperfect nature of the data available.

Heat lost by radiation and convection from the two retorts amounted to 143 therms or 1 therm per retort per hour; that lost by conduction to the water in the jackets amounted to 390 therms or 2·7 therms per retort per hour. It will be remembered that the throughput of each retort is approximately 1 ton of briquettes per hour and therefore the above figures indicate the loss of heat per ton of briquettes per hour.

The gases leaving the retorts had an average temperature of 220° C. at the off-take, but immediately after charging this dropped to 190° C., and then gradually rose to 270° C.

LABOUR AND POWER

The labour provided for the handling of the two retorts during the test was the same as that required for the handling of the plant when running at its full capacity of 100 tons per 24 hours (4 retorts). Two extra men were retained for sampling, &c.

This labour was made up as follows :—

	Men.
Handling of trucks (tractor driver, shunter)	2 (day shift)
Discharging briquettes to elevator boot ..	2 per 8-hour shift.
Charging and discharging retorts and coke handling	4 ,, ,,
Tar tanks	1 ,, ,,
Boiler and tar tanks	1 ,, ,,
Foreman	1 (day shift)
Total	27 men per 24 hours.

The above number of men required to handle the plant appeared quite normal in its present condition. If, however, mechanical means of discharging the briquettes from the wagons

were adopted one man alone would be sufficient for this duty. It also seemed apparent that one man could handle the charging of the retorts, but owing to the conditions at the time of the test two men were employed.

The amount of power utilised during the test could not be measured, but a list is given here of the various points at which power was being used.

Electric power supply : 440 volts, 3-phase, 50-cycles per sec.

Main briquette elevator.—5 b.h.p. Slip ring induction motor 560 R.P.M. Will elevate 8 tons of briquettes per hour.

Coke elevator and trommel.—10 b.h.p. Squirrel cage induction motor. 375 R.P.M. Screen and elevators are of ample capacity for coke from four retorts.

Blowers motor.—5 b.h.p. Squirrel cage type motor. Speed, 1,460 R.P.M. Connected directly to Keith Blackman fan.

Water sprayed cleaning and exhausting fans.—15 b.h.p. Slip ring induction motor. Speed, 1,460 r.p.m. Fans directly coupled. Normal working two fans running in series.

Water pumps (for cooling water to Lymn tower and fans).—20 b.h.p. Slip ring type. Speed, 1,460 R.P.M. Directly coupled to centrifugal pump, capable of delivering 10,000 gallons per hour, against a head of 100 ft.

Tar pumps (steam).—Small steam-driven Donkey pumps.

Steam.—All steam for the retorts, stills, pumps, heating coils from the exhaust waste heat boiler of 750 b.h.p. National Gas Engine in Colwick Estates Power House.

The power used in the briquetting plant was not considered as this did not enter into the test.

SUMMARY

A carbonising test is described as carried out by the staff of H.M. Fuel Research Station on an installation of retorts erected at the works of the Midland Coal Products Limited at Colwick Estates, Netherfield, Nottingham.

The installation consisted of four retorts, each capable of a throughput of one ton of briquettes per hour. Two only of the four retorts were used for the purpose of the test.

The retorts strongly resemble blast furnaces in appearance, and are fully described together with the condensing plant. They are internally heated by the combustion of a part of the material under process of carbonisation.

It was intended to carbonise only 2½ oz. ovoid briquettes made in a Yeadon press at the Midland Coal Products premises from Nottinghamshire Top Hard ½-in. washed slack, using 8 per cent. medium hard coal tar pitch as a binder, but as barely 100 tons of these were available it was decided to carry on the test for three days by utilising a 5-oz. ovoid briquettes made from the same materials by the Butterley Coal Company at Kirkby.

During the test, samples of the briquettes and of the products of carbonisation were collected, working conditions were observed and the labour required noted. The samples were brought to the Fuel Research Station for analysis.

The weight and heat balances do not give as valuable a criterion of the accuracy of the test as is usually the case, owing to the fact that the quantity of liquor produced was not measured, and that the quantity of air supplied was calculated from the volume of nitrogen in the gas. The carbon balance, however, which shows a gain of 0·1 per cent. may be taken as an indication that the test was quite satisfactory.

The following are the yields of products per ton of briquettes carbonised :—

Coke	.. ..	7·5 cwt.
Gas	.. ..	58,300 cubic ft. or 112·5 therms.
Tar	.. ..	21 gallons.
Liquor	.. ..	Calculated (about 42 gallons) from assay.

The coked material contains a remarkably small proportion of whole briquettes and a large proportion of breeze, the latter being of the order of 15 per cent. The larger pieces, *i.e.*, $\frac{1}{2}$-in. to $1\frac{1}{2}$-in. and over $1\frac{1}{2}$ in. in size, are very hard and stand transport very well. It contains about 2 per cent. volatile matter and although unsuitable for the ordinary open household grate, is quite well suited for use in stoves.

The tar, the yield of which is high, is of a very viscid nature containing small proportions of the lighter oils, a large fraction between 270° and 360° C., and about 63 per cent. pitch.

The volume of gas produced is also large, and resembles a semi-water gas made from bituminous coal, has a calorific value of 193 B.Th.U. per cubic foot, and is the principal product of the process.

The ammonia liquor is so diluted in the Lymn washer that ammonia recovery is commercially impossible.

The temperature of carbonisation is of the order of 1,200° C., but the briquettes are subjected to the action of the hot gas for about two hours before reaching the hot combustion zone. A certain amount of low temperature distillation may take place, but no appreciable amounts of unsaturated hydrocarbons or saturated hydrocarbons other than methane were detected on analysis of the gas, although they are always present in low temperature coal gases.

Details of the handling of the plant, of labour and power required are given.

CONCLUSIONS

(*a*) The installation of four retorts is capable of carbonising 100 tons of briquettes per day of 24 hours.

(*b*) The process cannot be classified with low temperature carbonisation as generally understood.

(*c*) The briquetting of the slack was not satisfactory, as a large amount of broken material was left in the wagons, but this drawback could easily be obviated by more care in handling the hot briquettes, using air-dry coal and a more suitable briquette elevator.

(*d*) The temperature conditions could be controlled more satisfactorily by adjusting the steam supply and keeping the rate of charging and discharging constant.

C. H. LANDER,

Director of Fuel Research.

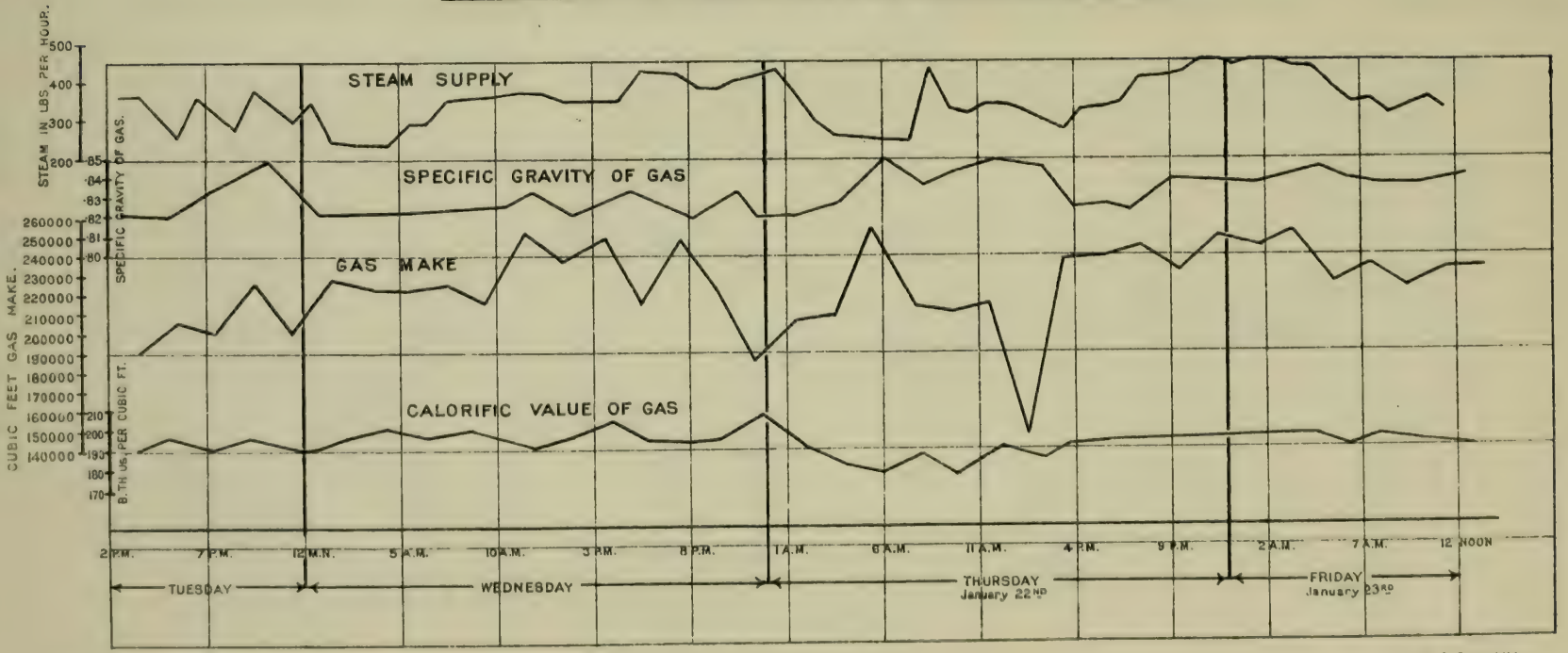
August, 1925.

MIDLAND COAL PRODUCTS LTD. NOTTINGHAM.

CARBONISATION TEST.

JANUARY 1925.

VARIATIONS IN GAS MADE & STEAM TO RETORTS.



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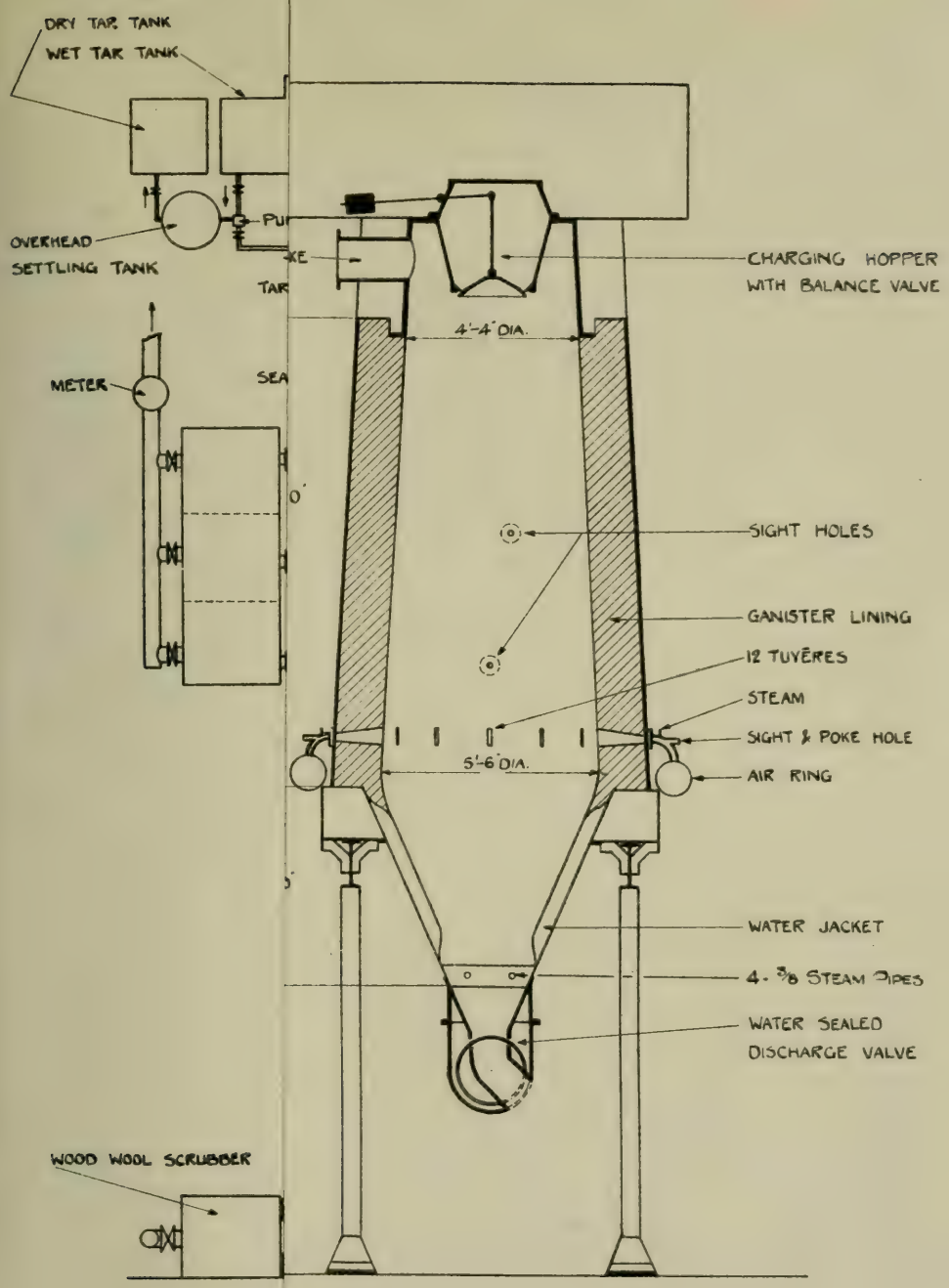

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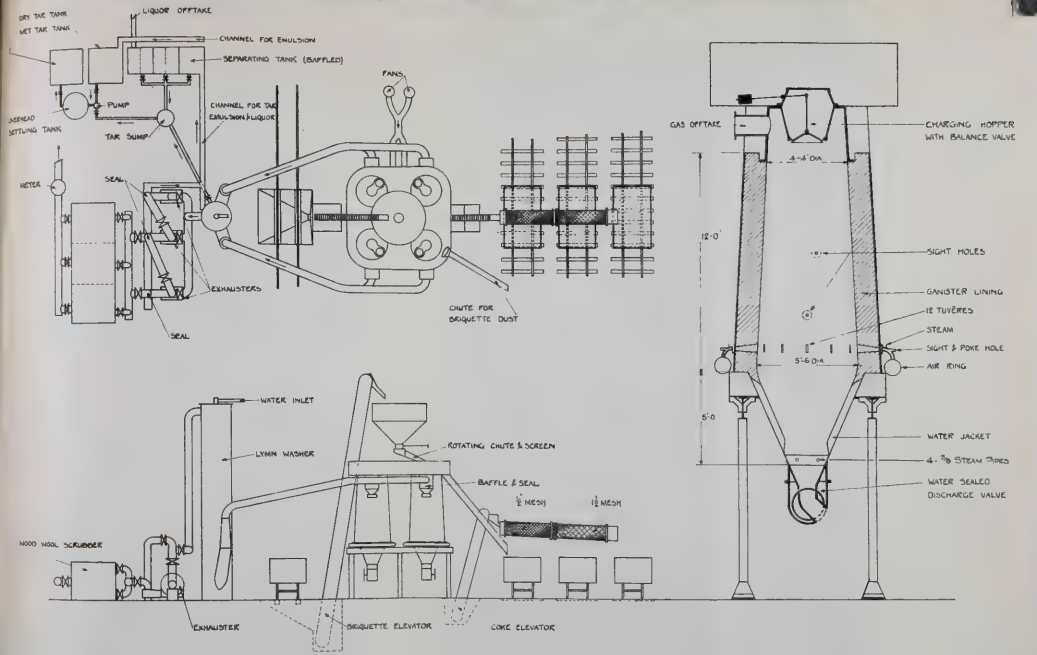

DIAGRAM OF PLANT

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APPENDIX

CONDITIONS UNDER WHICH THE DEPARTMENT IS PREPARED TO TEST PLANTS FOR LOW TEMPERATURE CARBONISATION OF COAL

The Department of Scientific and Industrial Research, Old Queen Street, S.W.1, is prepared to undertake in approved cases tests on plants for low temperature carbonisation. The objects of the test are to ascertain the quality and quantity of the yields of coke, tar oil, gas and ammonia, the throughput of the plant, working temperatures, and general ease and reliability of working. No charge will be made by the Department in respect of the tests, but applicants will be required to comply with certain conditions and to sign an Agreement embodying the terms on which this offer is made. Forms of application may be obtained from the Secretary, Department of Scientific and Industrial Research, 16 Old Queen Street, Westminster, S.W.1. The nature of these conditions can be ascertained from the following particulars, but the Department reserves the right to add to or alter them as may be thought necessary.

(1) Applicants will be required, before the Department can undertake a test, to supply full information as to the nature of the plant and results obtained and to afford facilities for the inspection of the plant by one or more officers of the Department, and generally to satisfy the Director of Fuel Research that the plant is giving reasonably good results and is of such a size that its performance will be comparable with that of a similar plant operating on a commercial scale.

(2) Tests will be under the continuous supervision of such members of the Fuel Research staff of the Department as the Department may decide, who may take as samples such amount as they may consider necessary both of the coal used and of the products.

(3) Applicants must at their own expense provide all necessary facilities including all material staff and labour required for running the plant, and for such assistance in taking samples and measurements as may be required by the Department or its officers supervising the test.

(4) Until the information referred to in paragraph (1) above has been supplied and a preliminary inspection of the plant has been made it is impossible to state what facilities will be required or to give any indication of the programme or possible duration of the test, which may vary from several days to several weeks according to circumstances.

The necessary facilities will in any event include proper arrangements for taking such measurements as will give a satisfactory weight balance between the input and output of the plant.

(5) Applicants will be permitted to have a representative present during the test who will be allowed to check any weights or measurements forming an integral part of the test.

(6) The decision of the supervising officer of the Department in charge of the test will be final in regard to all questions relating to the duration and conduct of the test and all weights, measurements and other matters in connection therewith.

(7) The Department reserves the right to publish a report on the test at any time at its discretion, but will before so doing consult the applicants, and any views the latter may express will receive consideration. A copy of the report will, at the request of the applicants, be furnished to them free of charge. Applicants will not be entitled to publish or communicate to third parties such report or any extract from or allusion to it without the consent in writing of the Department. Such consent may be conditional.

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